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# Prospective scenarios for the full solar energy development in Malaysia

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ABSTRACT

The limited availability of fossil energy carriers and environmental impact of energy consumption demand mid- and long-term strategies both for the rational use of energy and for increased renewable energy utilization. Despite the establishment of the National Energy Policy, there is still an obstacle in reaching those objectives and targets. In the 7th Malaysia Plan for instance, the government has highlighted that a third of the Government's total allocation of RM469 million for rural electrification programmes under the has been allocated for the provision of solar powered installations for rural and remote communities. This paper outlines a detailed description of various existing solar technologies, the understanding of each technology and its associated challenges, which will provide a suitable basis to recognize advantages and drawbacks in its implementation in Malaysia. The paper finally justifies some of the barriers in promoting the full scale utilization for the solar energy in Malaysia.



**Contents**



## 1. Introduction

Thousands of years ago, early humans used energy for their living such as lighting and heating for their living spaces and cooking by burning wood. Later, they moved their boats by using wind and they began to use falling water to generate electricity. Today, people use more energy than ever from a variety of sources to make living better. Our homes are comfortable, full of helpful and entertaining electric devices and we communicate instantaneously in many ways. Energy has become a fundamental part of people's daily lives as well as being vital to the social and economic progress of every country.

All the energy sources we are using today can be classified into two groups; renewable and non-renewable. Renewable energy is derived from natural processes that are replenished constantly. In its various forms, it derives directly from the sun, or from heat generated deep within the earth. Included in the definition are electricity and heat generated from solar, wind, ocean, hydropower, biomass, geothermal resources, bio fuels and hydrogen derived from renewable resources [1]. Record in 2005 has shown that the

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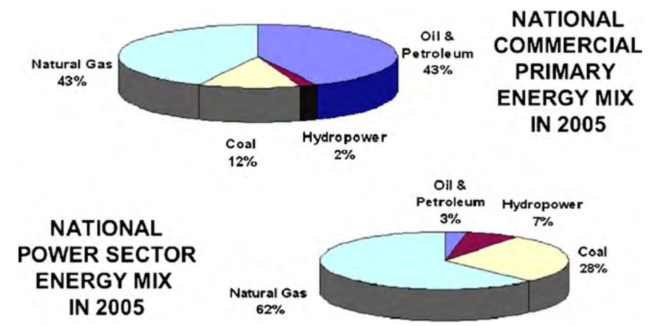



**Fig. 1.** Energy profile in Malaysia (source: TNB Research, Malaysia).

worldwide electricity generation was 17450 TWh out of which 40% originated from coal, 20% from gas, 16% from nuclear, 16% hydro, 7% from oil and only 2% from renewable sources such as geothermal, solar, wind, combustible renewable and waste [2]. Whilst for the same year in Malaysia, the percentages of the energy profile in Malaysia are mostly from natural gas for both national commercial primary and national power sector categories. This is shown in Fig. 1.

Non-renewable energy is energy sources that cannot replenish in the near future such as coal, petroleum and natural gas. Renewable and non-renewable energy sources can be used to produce secondary energy sources including electricity and hydrogen.

Several problems will be encountered due to the world's human population growth. Today, the major issues of the world are undoubtedly the energy problems and global warming [3–10]. Global warming occurs due to the increase in the average temperature of the Earth's near-surface air and the oceans, from the toxic gases produced by chemical factories and burning fossil fuels around the world. An alternative energy source must be used to reduce these emanations out into the atmosphere. Although, renewable energy such as solar and wind energy have been used for quite some time, there are numerous reasons why they have not emerged as the primary energy sources.

## 2. Potential of solar energy

Solar power generation is essential for a sustainable energy supply in the future. Naturally, there is ongoing research on solar energy throughout the world [11–22]. Solar irradiation is so abundant that the world's electricity demands can be provided to a large extent by solar power technologies. Energy experts expect that in the year 2050, over 50% and 80% of all electricity could be generated by renewable energy. Among the potential sources of renewable energy, solar thermal power plants are considered to be one of the most economic. Solar thermal power plants are expected to provide about provide about 10% of the world's electricity by 2050 (http://www.solarpowergroup.com/). Fig. 2 shows the direct solar irradiation around the world.

The following sections will outline various existing solar technologies. The understanding of each technology and its associated challenges will provide a suitable basis to recognize advantages and drawbacks.

## 3. Photovoltaic energy

Photovoltaic (PV) cells are semi-conductor devices, which converts sunlight energy directly to electrical energy. Conventional photovoltaic cells are made of crystalline silicon that has atoms arranged in a three dimensional array, making it an efficient semi-conductor. Although, this material is most commonly used for generation of electricity, it also has associated drawbacks, such as high material costs for silicon, costly processes for purifying silicon and manufacturing wafer, additional processes for assembly of modules and the bulky and rigid nature of the photovoltaic panels [23]. Fig. 3 depicts a typical PV cell under illumination.

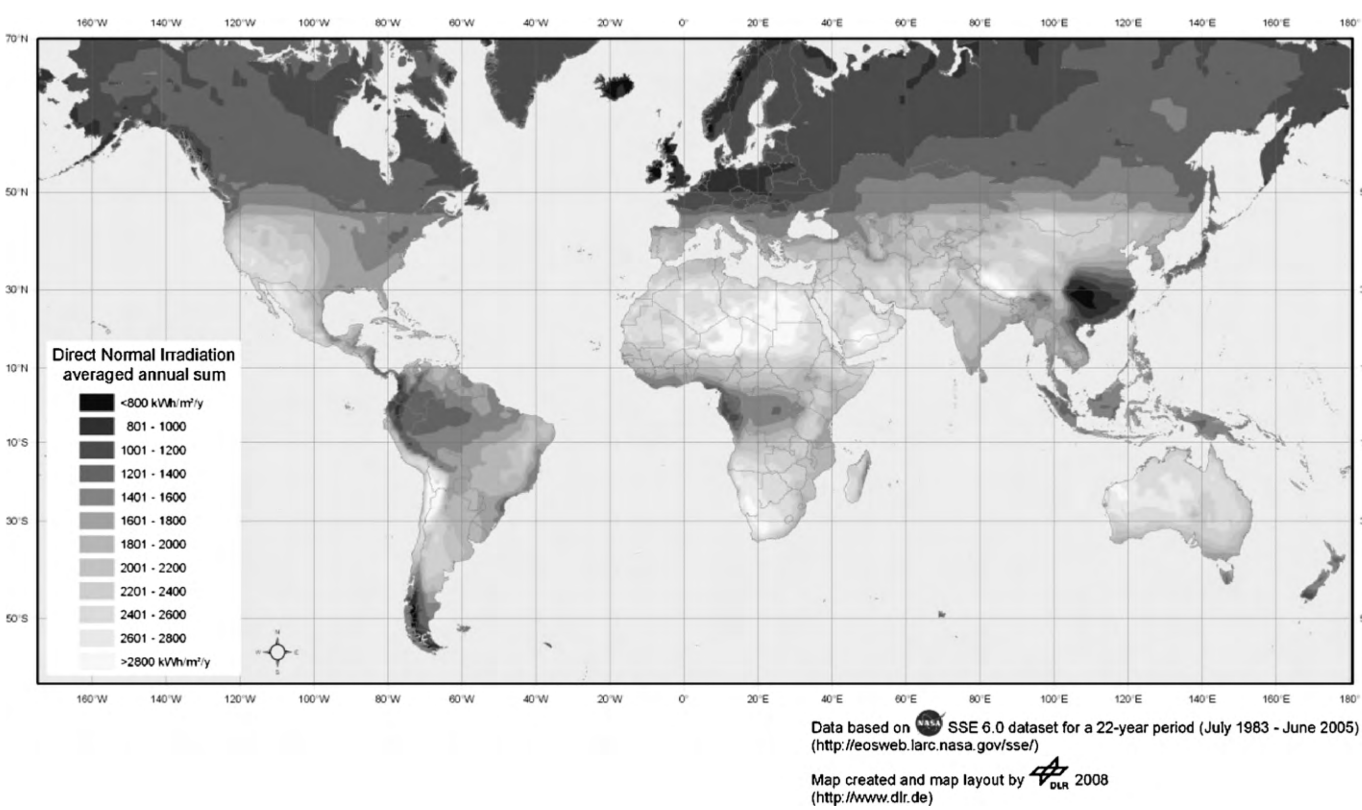



**Fig. 2.** The classification of direct normal irradiation around the world (source: http://www.dir.de, 2009).

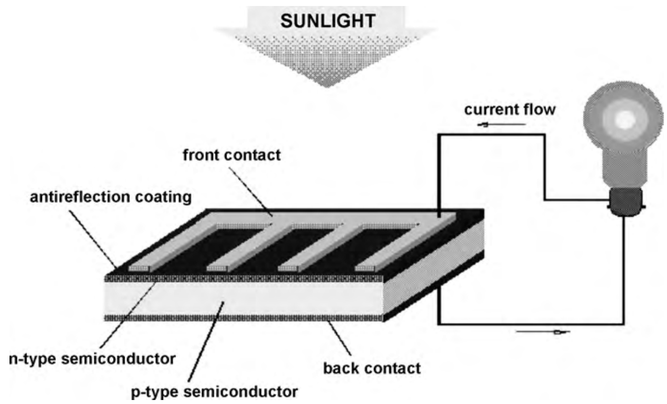



**Fig. 3.** Photovoltaic cell under illumination (source: The University of New South Wales, Australia, 2009).

PV modules are usually divided into two groups of monocrystalline and polycrystalline silicon. Monocrystalline silicon is a crystalline in which the crystal lattice of the entire silicon sample is continuous and unbroken at the edges of the sample, with no grain boundaries. However, polycrystalline silicon (also poly-silicon or poly-Si) is made up of a number of smaller crystals known as crystallites. In this context, the word crystalline refers to both monocrystalline and polycrystalline technologies combined [24].

The beauty of the PV system is that it does not involve any moving parts or emissions of any kind during operation. The main attractiveness of the PV technology is low maintenance, and no pollution, and has positioned PV to be the preferred power technology for many remote applications for both space and on the ground. Photovoltaic (PV) technology is expected to be a leading technology to solve the issues concerning the energy and the global environment due to several advantages of the PV system [25].

The photovoltaic effect was first recognized in 1839 by French physicist A.E. Becquerel. However, the modern age of solar power technology arrived in 1954 when Bell Laboratories, invented the first practical solar cells with 6% of efficiency for US satellite (http://www.sunlightelectric.com/). This crucial development stimulated funding from several governments into research for improved solar cells. It showed a significant growth on PV technology after commercialization on 1970s.

In 2001, the total annual manufacturing output of all solar PV companies was about 300 MW. In 2005, manufacturing output of the solar PV industry hit 1500 MW of PV modules, and it surpassed 2000 MW in 2006 [26]. With installed, unsubsidized costs, now coming close to $0.20/kWh in the best applications while average electric rates from utilities are less than $0.10/kWh. Although, photovoltaic electricity is three to five times more expensive than other conventional grid power systems, PV is turning into a mainstream business with familiar names such as BP, GE, Sharp and Shell [26]. Today, ongoing industry-government researches and development programs are emerging potentially lower cost and higher efficient photovoltaic technology, and its use in commercial and demonstration applications is beginning. Some developing countries are rapidly using the newer PV technologies, which makes grid-competitive photovoltaic electricity, probably 10–20 years away in the developed world [27].

The average cost for PV technology in 2006 was roughly $7–10 per peak watt installed [26]. On the other hand, the average module cost is about $4.34/W on November 2009. The lowest retail price for a multi-crystalline silicon solar module is $2.48 per watt from a US retailer. The lowest retail price for a monocrystalline silicon module is also $2.70 per watt, from an Asian retailer (http://www.solarbuzz.com). SunPower Corporation, a leader in PV industry, reported in 2006 that it reached 22% efficiency at the cell level. It currently offers PV modules at 18% peak efficiency. However, climatic effects such as dirt accumulation and temperature rise as well as aging, which causes a gradual increase of the device's internal leakage conductance, lowers the efficiency.

### *3.1. Thin-film photovoltaic*

It is evident that since the past 15–20 years various thin-film technologies have been under development for reducing the amount of light absorbing material required in producing a solar cell. Still, one of the biggest challenges in thin-film technology is the cost of solar PV to cost parity with other conventional retail electricity. Since silicon is the key contributor to the cost of PV technology, using less silicon will have a considerable effect on the cost reduction of the PV technology. The panels are usually made in the form of a monolithic piece of glass, upon which various thin-films are deposited, although a number of firms are working on depositing the materials on a flexible substrate, such as stainless steel or plastic (http://www.investorideas.com).

Thin-film solar cells are primarily produced from three different types of materials. Although, these cells have differences in material and technology, they also have promise versus other cells. Conversion efficiency is one major metric for solar material, which represents how much of the sun's energy the material can convert into electricity. Today, the laboratory efficiency of the Amorphous Silicon (a-Si) is 12.3%, Cadmium Telluride (CdTe) is 16.5% and Copper Indium Gallium Selenide (CIGS) is 19.9% (http://www.miasole.com/). Amorphous Silicon had the largest share of the thin-film market as of the end of 2005. It has been researched for the longest period, may be the best-understood material of the three and has been commercial for the longest duration. Cadmium Telluride has the remaining share of the market and is ramping up very rapidly, with Copper Indium Gallium Selenide having a negligible share of the thin-film market, although with great potential, but is the least understood and least developed of the three materials.

Advantages of Thin Film Technologies over Conventional Crystalline Silicon are lower cost of production than conventional silicon processes, lower production facility cost per watt, use of far less material, as little as 1/500th the amount used in standard silicon cells, and lower energy payback. It also produces more useable power per rated watt, provides superior performance in hot and overcast climates, has the ability to be attractively integrated into buildings and produces the lowest cost power (http://www.investorideas.com). According to the Solarbuzz[1], the cheapest thin-film module costs $1.76/Wp in November 2009 and First Solar[2], Inc. a public trading company-announced on Feb. 24, 2009, that it reduced manufacturing cost for solar modules in the fourth quarter to 98 cents per watt, breaking the $1 per watt price barrier (http://investor.firstsolar.com).

Although, thin-film cells are not as efficient as conventional crystalline silicon-especially as they are not used in tandem devices, it is believed that thin-film will be a dominant PV technology in the future. Many also believe that, the likelihood of significant reduction of module cost has many opportunities to increase the efficiency that surely will reduce the overall cost of thin-film technology [28].

### *3.2. Concentrating photovoltaic*

Concentrating photovoltaic (CPV) systems uses a large area of lenses or mirrors to focus a large area of sunlight on a small photovoltaic cells, which converts sunlight energy into electrical

[1] http://www.solarbuzz.com.
[2] http://www.firstsolar.com/.

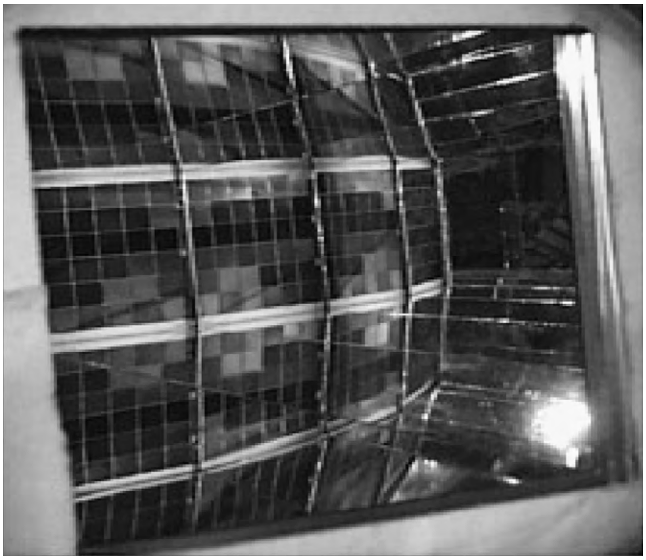


**Fig. 4.** A concentrating photovoltaic system uses a dense array of high-efficiency silicon cells [29].

energy in the same way that the conventional photovoltaic technology does (http://www.zytech.es/, http://www.nrel.gov/). The attractiveness of the CPV technology over the standard PV technology is that it uses less semiconducting material by replacing most of the PV cell area with a set of reflectors in order to reduce the cost. Additionally, increasing the concentration ratio will improve the performance of general photovoltaic materials (Fig. 4).

Concentrating photovoltaic technology offers the following advantages:

- Potential for solar cell efficiencies greater than 40%.
- No moving parts.
- No intervening heat transfer surface.
- Near-ambient temperature operation.
- No thermal mass and a fast response.
- Reduction in the cost of cells relative to optics.
- Scalability to a range of sizes (http://www.nrel.gov/).

Despite the advantages of CPV technologies, their application has been limited by the complexity and due to the cost of focusing, tracking and cooling equipment, it is now only reaching commercial viability. Even if using expensive cells, a CPV system with concentration ratio of 500 (or 500 suns) generally uses 1/500, the amount of PV cell surface area as does conventional PV, so the price of the PV cell constitutes a smaller cost consideration for CPV. Energy Innovations[3] and SolFocus[4] are two leading companies pursuing serious research efforts in CPV technology. SolFocus projects the cost of its Gen1 CPV system to become as low as $1/W at 1 GW production level [30]. Further, SolFocus Gen2 systems are expected to achieve 26% efficiency and a record cost less than $0.50/W.

## 4. Residential water heating

Residential or domestic solar water heaters can reduce the energy consumption as much as 50% and can be a cost effective way of generating hot water for residential homes, especially in colder countries. It is believed that 15–20% of the energy

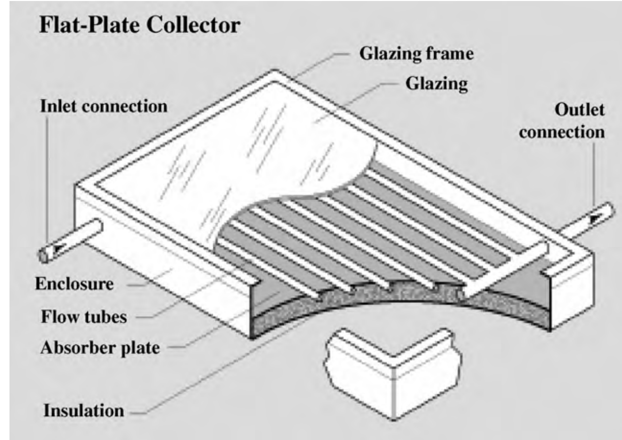



**Fig. 5.** Flat plate collector (source: US Dept of Energy, 2009).

consumption for an average family is domestic hot water for laundry, dishes, showers and long soaks in the tub. Solar water heating systems have both a well-insulated storage tank and solar collector modules. Solar collectors are designed to absorb solar radiation, then convert it into heat and transfer that heat to water, fluid or air that travels to storage, either a solar tank or a water heater. This process continues until the tank is hot for evening and morning use whenever enough sun is available (http://www.solar-tec.com). These thermal systems can be used for many applications such as solar water heating systems, solar pool heaters and solar space-heating systems. There are three types of collectors.

### 4.1. Flat-plate collectors

Flat plate collectors, depicted in Fig. 5, are the most common type of solar water heating systems for residential and commercial applications (http://www.daviddarling.info). A flat-plate collector consists of an insulated metal box with a glass or plastic cover (the glazing) and a dark-coloured absorber plate. Basically, it collects the suns solar radiation and transfers it to homes.

Flat-plate collectors heat the circulating fluid to a temperature considerably less than that of the boiling point of water and are best suited to applications where the demand temperature is 30–70 °C (86–158 °F). The efficiency of flat plate collectors varies from manufacturer to manufacturer, and system to system, but usually ranges from as low as 20% to as high as 80% (http://www.daviddarling.info & http://www.cogeneration.net).

### 4.2. Evacuated-tube solar collectors

An evacuated-tube collector consists of parallel rows of glass tubes connected to a header pipe. Each tube has the air removed from it to eliminate heat loss through convection and radiation (http://www.cogeneration.net/). Typical of an evacuated-tube collector is shown in Fig. 6.

These types of collectors fall into two main groups which are direct-flow evacuated-tube collectors and heat pipe evacuated-tube collectors. Evacuated-tube solar collectors are highly efficient and achieve high-temperatures, in the range 170 °F (77 °C)–350 °F (177 °C). However, it is quite expensive, with unit area costs typically about twice that of flat-plate collectors.

### 4.3. Compound parabolic collectors

Compound parabolic collectors, better known as CPCs, are another family of collectors that enhance the efficiency of evacuated-tube collectors through non-imaging optics [32]

[3] http://www.energyinnovations.com.
[4] http://www.solfocus.com.

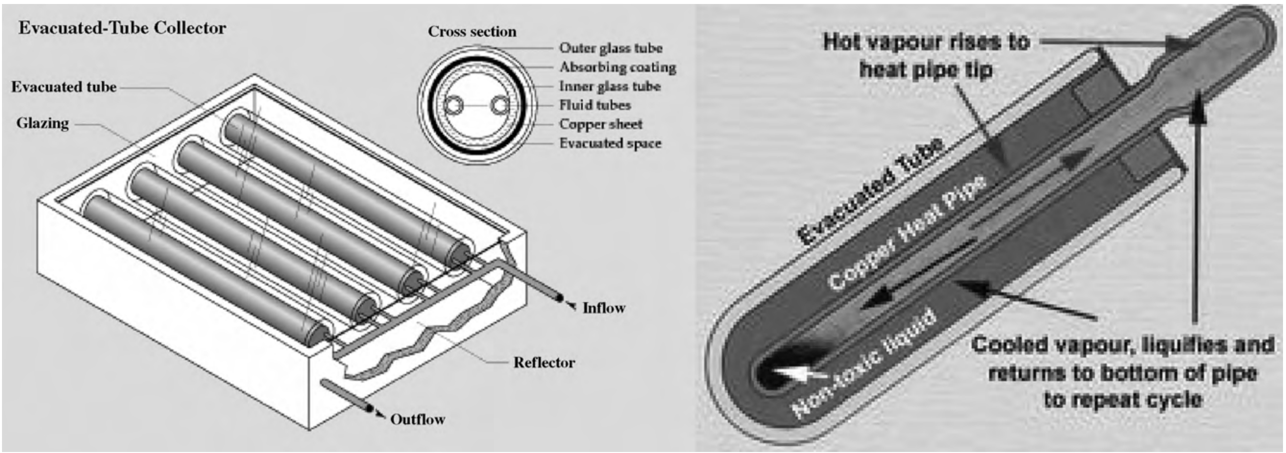



**Fig. 6.** Direct-flow evacuated-tube collectors and heat pipe evacuated-tube collectors [31].

and it can achieve temperatures close to 450 °F (232 °C) without tracking due to the wide acceptance angle (http://www.solargenix.com) (Fig. 7).

The advantages of the new solar collector are its great versatility, the low-costs and higher energy efficiency. Furthermore, all the mentioned solar collectors have simple components and can be manufactured by relatively easy processes compared to that of PV or thin-film technologies. A solar water heater is a long-term investment that will save you money and energy for many years. Like other renewable energy systems, solar water heaters minimize the environmental effects of enjoying a comfortable, modern lifestyle [33]. A 25-tube evacuated-tube collector system with gross collector area of 2.6 $m^2$ could retail for about $769 (http://beyondoilsolar.com).

## 5. Concentrating solar power

Concentrating solar power (CSP) systems generates electricity by using sun as heat source. The three main types of concentrating solar power systems are: solar parabolic trough, power tower systems and dish–engine.

### 5.1. Solar parabolic trough

Fig. 8 shows a parabolic trough power plant's solar field, which consists of a large, modular array of single-axis-tracking parabolic trough solar collectors. Many parallel rows of these solar collectors span across the solar field, usually aligned on a north-south horizontal axis. The basic components of a parabolic trough solar field are the solar collector assembly or SCA. A solar field consists of hundreds or potentially thousands of solar collector assemblies. Each solar collector assembly is an independently tracking, parabolic trough solar collector composed of the following key subsystems: Concentrator structure, mirrors or reflectors, linear receiver or heat collection element and collector balance of the system (http://www.nrel.gov/).

The system continuously focuses the sun from east to west during the day to ensure that it always receives full radiation from the sun. Heat transfer fluid in the absorber tube converts the heat from the sun into electricity. The receiver is usually metallic and embedded into an evacuated glass tube to reduce the heat loss. A special high-temperature coating additionally reduces radiation heat losses [35]. Temperatures of the heat transfer fluid at the receiver can reach 390 °C. The heated working fluid may be used for a medium temperature space or process heat, or to operate a steam turbine for power or electricity generation. The efficiency of a solar thermal power plant is the product of the collector efficiency, the efficiencies associated with transferring heat to steam-cycle, and steam-cycle efficiency. The collector efficiency depends on the angle of incidence of the sunlight and the temperature in the absorber tube, and can reach values up to 75%. Thermal losses are usually below 10%. Altogether, solar thermal

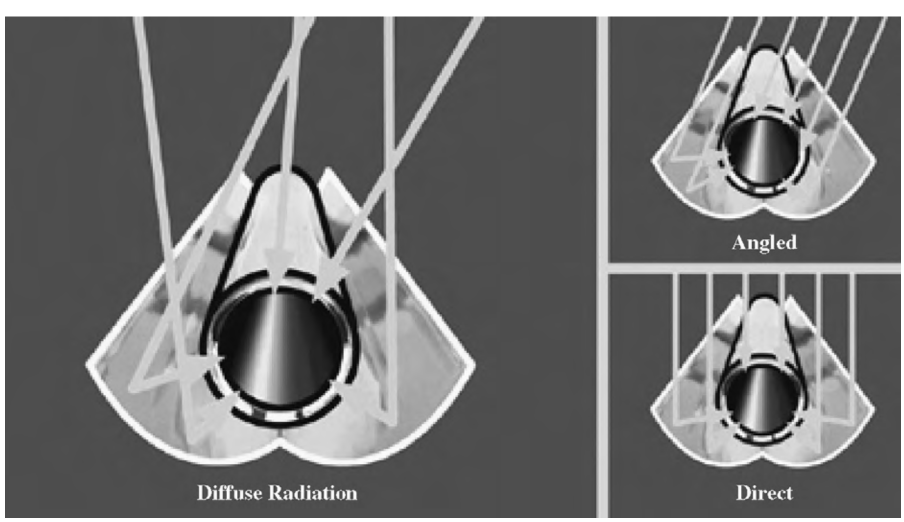



**Fig. 7.** CPC mirror maximises energy yield, directing as much available radiation onto the evacuated-tube (source: INS-SOLAR, 2009).

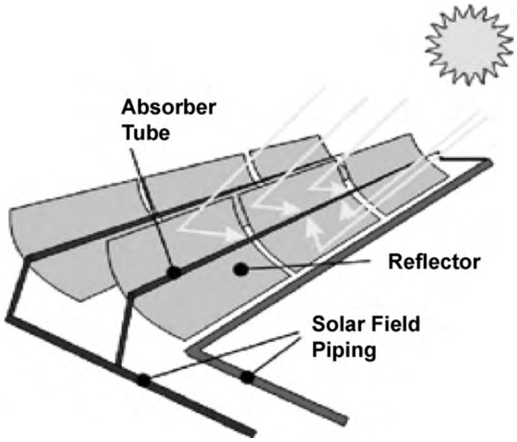



**Fig. 8.** Parabolic trough system [34].



**Fig. 9.** Solar tower system [36].

trough power plants can reach annual efficiencies of about 15% with a capacity factor of about 55% [33,35].

According to US National Renewable Energy Laboratory, NREL[5], All together, nine trough power plants, also called Solar Energy Generating Systems (SEGS) were built in the 1980s in the Mojave Desert near Barstow, CA. These plants have a combined capacity of 354 MW and today it generates enough electricity for approximately 500,000 people. These types of the systems are currently the most proven solar thermal electric technology due to the successful operation of these nine large commercial scale solar power plants with size ranging from 14 to 90 MW (http://www.solarpaces.org/). Currently, the commercial plants utilizing solar parabolic troughs are considered as hybrids because it operates on natural gas or fossil fuels during the night hours and cloudy days. However, the amount of natural gas is limited to a maximum 25% of electricity production, allowing the plant to qualify as a renewable energy source [31]. Historically, parabolic trough plants have been designed to use solar energy as the primary energy source to produce electricity. These plants can operate at full rated power using solar energy alone given sufficient solar input. During summer months, the plants typically operate for 10 to 12 h a day at full rated electric output (http://www.solarpaces.org/).

The level of energy cost from trough systems has declined over the years from greater than 25¢ per kilowatt-hour (kWh) in 1984 to 10–12¢/kWh today, with experience and improved technology. They also revealed that part of the cost reduction at the SEGS plants are the direct result of a project designed to reduce the operation and maintenance (O&M) costs with improved plant efficiency. KJC-operating company of Kramer Junction, California, and the operator of five of the SEGS plants-estimated that there would be 30% reduction in O&M costs with improvement of performance of the plant. This is approximately the net present value of $42 million in cost savings in the next 20 years of plant operation. Furthermore, many of the cost reduction strategies developed for the SEGS plants are applicable to other solar power technologies, such as dish–engine systems and solar power towers [31]. Ausra[6], a start up company located in Palo Alto, CA, has recently attracted considerable amount of venture capital (VC) money for its proposed technology. Ausra's new technology is the Compact Linear Fresnel Reflector (CLFR), which utilizes a fixed pipe absorber and simple, nearly flat, rotating mirrors to dramatically reduce the cost of the power plant. The water boils to generate high-pressure steam, and from that point on, the process is the same as a conventional power plant as explained above. They are currently building a 30 MW power plant, and are in the process of scaling up to 2000 MW over the next 3 years.

### 5.2. Solar power tower

Solar power towers are used to convert the sunlight into useful electric power by focusing concentrated solar radiation on a tower-mounted heat exchanger (receiver) (http://www.solarpaces.org/). Solar power tower plant system, as shown in Fig. 9, consists of a large number of sun-tracking mirrors called heliostats to reflect the incident sunlight onto the receiver. The vast amounts of energy coming from reflected sun rays will be concentrated at top of the receiver – the tower in the middle-which heats up the fluid (water or molten salt) in the receiver and generate steam at a temperature of approximately 550–1500 °C. These steams are used to turn the conventional turbine to produce electricity in the range of 30–400 MWe (http://www.nrel.gov/).

Although, solar power tower systems are used less commercially than solar parabolic trough systems, the components and experimenting systems have been field tested in the last 25 years for countries such as Russia, Italy, Spain, Japan, France and the United States, with output power ranging from 0.5 to 10 MW [34,35]. Still there are many differences in the technology used in solar tower systems around the globe. Early solar power towers utilized steam as a working or heat transfer fluid, but current US designs utilizes molten nitrate salt as the heat transfer fluid because of its better heat transfer capability and energy storage capabilities. In European designs, they use air as a heat transfer medium because of its high-temperature and its good hand ability (http://www.azocleantech.com/). Variety of fluids has been researched and tested for transfer of the sun's heat, such as water, air, oil and sodium, after which molten salt was selected as the best. There are many advantages of using molten salt as a heat transfer fluid in solar power towers. It provides an efficient, low-cost medium in which to store thermal energy, and also the operating temperatures are compatible with today's high-pressure and high-temperature steam turbines apart from being non-flammable and nontoxic.

On the other hand, it is important to note that solar towers are economically viable and cost effective only in 50 or 100 MW units. Compared to any other concentrated solar power (CSP) technology it also requires the largest amount of space per unit of produced power and a high amount of water. This may become a crucial issue from a practical and an environmental point of view since these plants will typically be deployed in deserts that often lack water and have fragile landscape. Many other functions will affect the efficiency of the system including the heliostat optical performance, the mirror cleanliness, the accuracy of the tracking system,

[5] http://www.nrel.gov/docs/legosti/fy98/22589.pdf.
[6] http://www.ausra.com.

and apart from that the wind effects and the efficiency of the steam turbine/generator are critical functions that will influence the absorber temperature. Solar power tower plants can also be hybridized with conventional fossil-fired plants like the natural gas combined-cycle and coal-fired or oil-fired Rankine plants. In hybrid plants, the solar energy can be used to reduce fossil fuel usage or boost the power input to the steam turbine.

Today, many areas of the developing world like India, Egypt and South Africa, are in need of new peaking and intermediate power sources and these locations are ideally suited for power tower development. When non-polluting energy sources are becoming more and more favourable, power towers will have high value because the thermal energy storage allows the plant to be dispatch able. Consequently, the value of power is worth more because a power tower plant can deliver energy during peak load times when it is more valuable. Energy storage also allows power tower plants to be designed and built with a range of annual capacity factors (20–65%) (http://www.solarpaces.org & http://www.azocleantech.com). A new solar power tower, known as Solar Tres, is being constructed in Spain [37]. It is a 17 MWe plant with 15 h of thermal energy storage and estimated 6500 h of operation per year (i.e. 74% capacity factor). The NREL has estimated that by 2020, electricity could be produced from power towers for 5.5 cents per kWh (http://www.nrel.gov/). Google.org hopes to develop cheap, low maintenance, mass producible heliostat components to reduce this cost in the near future (http://www.google.com).

### 5.3. Solar dish–engine systems

Solar dish–engine systems convert the energy from the sun into electricity at a very high-efficiency. As shown in Fig. 10, it consists of a parabolic shaped point focus concentrators in the form of a dish. The solar dish focuses the sun's rays onto a receiver, typically two-axis tracking system to follow the sun which has concentration ratio of above 2000. Tracking in two axes is accomplished in either azimuth-elevation tracking or polar tracking. The receiver transmits the energy to an engine mounted on the receiver that generates electric power [38]. Because of the high concentration ratios achievable with parabolic dishes and the small size of the receiver, solar dishes are efficient at collecting solar energy at very high-temperatures approximately over 700 °C and pressures as high as 200 bar. Currently, tests have shown that solar-to-electric conversion efficiencies as high as 30% and it is significantly higher than any other solar technology.

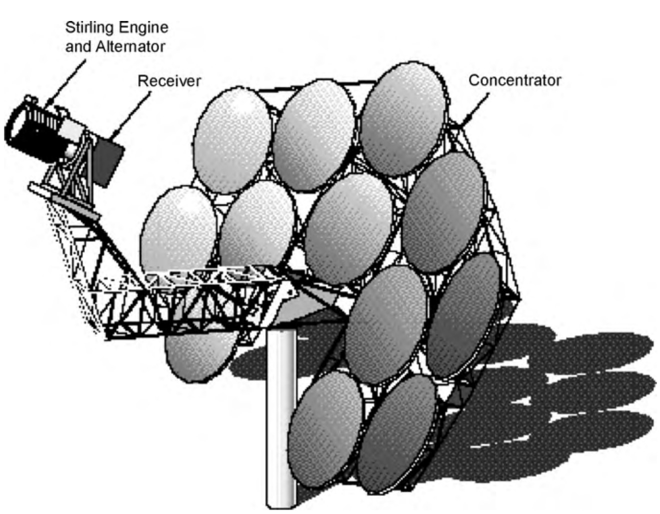



**Fig. 10.** Solar dish system (source: Solstice – Centre for Renewable Energy and Sustainable Technology).

**Table 1**
Cost of concentrated solar–thermal–electric technologies.

| Specification/type | Solar dish–engine | Parabolic trough | Solar power tower |
|---|---|---|---|
| Standard plant size, MW | 2.5–100 | 100 | 100 |
| Max efficiency, % | 30 | 24 | 22 |
| Specific power, W/m$^2$ | 200 | 300 | 300 |
| Basic plant cost, $/W | 2.65 | 3.22 | 3.62 |
| Total US installation, MW | 0.118 | 354 | 10 |
| Largest unit in the US, MW | 0.025 | 80 | 10 |
| Demonstrated system, h | 80,000 | 300,000 | 2000 |

The main benefits of the solar dish–engine systems are that it has environmental, operational and potential economic advantages over more conventional power generation. It produces zero emissions when operating on solar energy, operates more quietly than diesel or gasoline engines, are easier to operate and maintain than conventional engines, starts up and shuts down automatically; and also operates for long periods with minimal maintenance [38]. On the other hand, the main disadvantage of this type of engine is their manufacturing cost, which is mainly determined by the materials used for the hot side heat exchanger (stainless steel, high-temperature alloys or ceramic materials) and by the design of the cooling system. These engines have individual units ranging from 10 to 25 kW, solar dish–engine systems and are well-suited for non-traditional power generation as well as being very durable because of their size. Like photovoltaic systems, these systems can operate independently of power grids in remote sunny locations for uses such as pumping water and providing power to people living in isolated villages. These systems can also be combined with natural gas and the resulting hybrid provides continuous power generation like other conventional solar energy systems.

Now, electricity generation costs in solar dish–engine systems are quite higher than those for trough or tower power plants. A number of prototype dish–engine systems are currently operating in Nevada, Arizona, Colorado and Spain. High levels of performance have been established and durability remains to be proven, although some systems have operated for more than 10,000 h [39–41]. Table 1 highlights the cost of Concentrated Solar–Thermal–Electric technologies.

Infinia Corporation[7] and Stirling Energy Systems, Inc. (SES)[8] have been successful in attracting venture capital or VC capital and long-term agreements with utilities to design and construct solar dish–engine plants. SES power plants will be constructed in the Imperial Valley and Mojave Desert by 2012–2014 with capacities of 300–500 MW [41].

### 5.4. Limitation and barriers developing solar energy in Malaysia

There are many limitations and barriers that should be overcome implementing solar energy in Malaysia. Here are some critical points that can be highlighted:

- One of the most important thing Government and Non-Governmental Organization (NGO) can do is creating awareness among the public such as benefits of solar energy, financial aspects, legal requirements and environmental advantages.
- Government can also provide details of information regarding implementation of the solar technology and build technical capacity.
- Implementing supportive policies such as imposing effective pricing laws and giving practical support to those who implement renewable energy technology.

[7] http://www.infiniacorp.com.
[8] http://www.stirlingenergy.com/.

- It's essential to reduce the subsidies for fossil fuel as a prerequisite for technological development of solar technology and develop a market for solar energy with attractive prices for users as well as suppliers.
- Establishing dedicated credit or loan facilities that make solar power attractive and reducing the taxes and customs duties on equipment related to solar energy.
- Although Malaysia set a clear and ambitious target of 5% for the use of renewable energy use out of total electricity production in Eighth Malaysian Plan, it does not materialise due to poor implementation.
- Independent power producers must get access to national power grid and Tenaga Nasional Berhad (TNB) should give preference on renewable energy projects.
- Market has limited experience and lack of technical expertise locally.

## 6. Conclusion

An overview of prospective scenarios for the solar energy development in Malaysia has been presented in detail in this paper. The study examines various existing solar technologies, the understanding of each technology and its associated challenges for which will provide a suitable basis to recognize advantages and drawbacks in its implementation in Malaysia. With the availability of the resources for the full scale development, there is a great potential for Malaysia to move from fossil-based generation towards the RE. More roles and supports are needed from the Government in overcoming the barriers should the Government decided to achieve its objectives and targets. With the availability of the technologies and the policies as the guides, there are no longer issues on the limited resources, higher crude oil prices and climate change.

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